Real-Time Web-based Image Distribution using an Airborne GPS/Inertial Image Server

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BIOGRAPHY

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ABSTRACT

The use of web-based tools for viewing and sharing imagery has expanded significantly over the last few years. Web services such as Google Earth have whet the public's appetite for georegistered and georectified imagery. While there is a large amount of registered imagery available for display on these Servers, much of the data is old and outdated, some by many years. NAVSYS has developed a GPS/inertial/video product (GI-Eye) that can be used to collect georegistered imagery in real-time. We have combined this with a GeoReferenced Information Manager (GRIM) Server that allows this imagery to be converted to a georectified image. In this paper, we describe the GI-Eye and GRIM products and the auto-mosaicing capability that they provide. We also include examples of mosaic imagery that was generated during flight tests of the system.

INTRODUCTION

The use of georeferenced imagery across the Internet is becoming prevalent thanks to the development of web-based location servers such as Google Earth, TerraServer and Yahoo Local. One of the most frequently asked questions for these services is "*How old is your data?*" The answer posted by Google to this question is "*Google Earth acquires the best imagery available, most of which is approximately one to three years old.*"[1] Users of these services are continually asking for more timely, high resolution data. The military also has a similar need to provide near real-time situational awareness to ground troops. This is currently provided using streaming video, but this does not provide the same geospatial awareness that the 3D Google Earth-like tools provide. Civil agencies such firefighters, search and rescue teams, law enforcement, 911 emergency operations, border patrol operations, traffic monitoring systems, and geological survey crews could also benefit from a near real-time web-based geospatial visualization capability.

To address this need for real-time geospatial awareness, NAVSYS has developed the GI-Eye product which provides the capability to generate precision mensurated imagery directly on the aircraft collecting the data. The GI-Eye system integrates GPS, inertial and digital camera data to provide autonomous registration capability for imagery without requiring access to any Ground Control Points (GCPs). This provides real-time, high quality registered imagery at a 1-Hz rate. The GI-Eye system has been combined with an Enterprise Server, termed the GeoReferenced Information Manager (GRIM) that uses this mensurated imagery to auto-generate mosaics as the data is being collected. With this approach, a near real-time geospatial view of the environment can be generated in a format that can be viewed using the current web-based geospatial visualization tools.

GI-EYE SYSTEM DESIGN

The GI-Eye product is offered to sensor manufacturers and systems integrators to provide an embedded precision autoregistration capability for electro-optic (EO), infra-red (IR) or other focal plane array (FPA) type sensors.

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This product has been integrated with a variety of different digital cameras and sensors. A ground-based system being used for tactical surveying and targeting by the National Geospatial-Intelligence Agency (NGA) is shown in Figure 1. GI-Eye is also being used by FLIR in their StarSAFIRE® III product (Figure 2) where it provides a GeoPointing[2] capability to stabilize their high resolution imaging to a point on the ground selected by the operator.

Figure 1 NGA Tactical Surveying and Targeting System (TS2)

Figure 2 FLIR StarSAFIRE III[3]

The GI-Eye product provides the capability to precisely time mark each camera image and uses NAVSYS' proprietary InterNav kinematic alignment algorithm[4] to measure the precise position and attitude of the camera using the GPS and inertial sensor data. The GI-Eye system auto-registration capability provides the location and pointing angle of the sensor with each image and also sensor calibration data from which the coordinates of each pixel in the image can be derived. This information can be used with a Digital Elevation Model (DEM) to extract the individual pixel coordinates of each image (Figure 3). It can also be used to derive a 3D DEM from multiple images through photogrammetry. With the precision GI-Eye meta-data, there is no need for any GCPs to be used for image registration. A self-calibration capability has been designed into the GI-Eye system that allows for estimation of camera misalignment, focal length and lens distortion parameters. Figure 4 shows the improvement in the targeting precision that results from applying these calibration parameters to a test set of data collected against a known reference point.

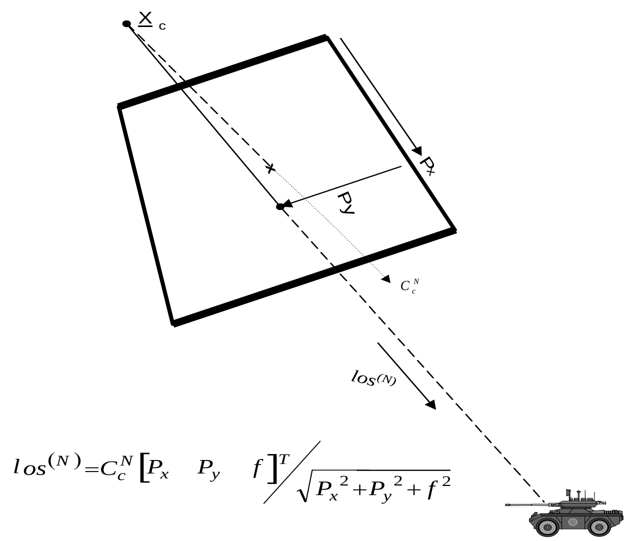

Figure 3 GI-Eye Position and Attitude Image Registration

NAVSYS' technology has resulted in improved position and attitude accuracy using relatively inexpensive inertial components. This allows georegistration accuracies of 1-2 meters to be provided when flying at an altitude of 1,000 feet without requiring the use of any ground truth[5].

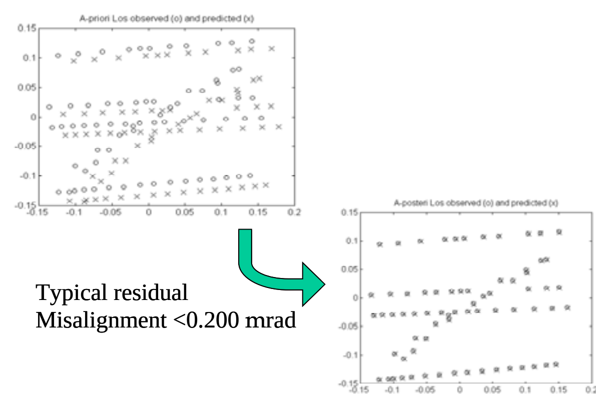

Figure 4 GI-Eye Calibration Results

UNMANNED AIR VEHICLE (UAV) PAYLOAD

The GI-Eye has also been configured for use in a UAV payload. Our approach is to use a modular design that enables sensor upgrades over time with only software configuration changes. This allows us to take advantage quickly of advances in sensor and inertial subsystems. The GI-Eye system components are shown in Figure 5. From left to right, the figure shows the digital camera,

power converter board, IMU interface board, single board computer, and the BAE Multisensor Inertial Measurement Unit (MIMU). The hard drive is positioned under the single board computer. In Figure 6 a drawing is shown of these components assembled in the ARES UAV payload. ARES is a small UAV developed by the Research and Engineering Center for Unmanned Vehicles (RECUV) at the University of Colorado at Boulder for use in flight testing advanced unmanned air system concepts[6]. The camera and IMU can be either fixed in the aircraft or mounted inside a gimbal to allow geopointing to targets of interest. The individual components are described below. The size, weight and power specifications for the GI-Eye UAV payload are included in Table 1.

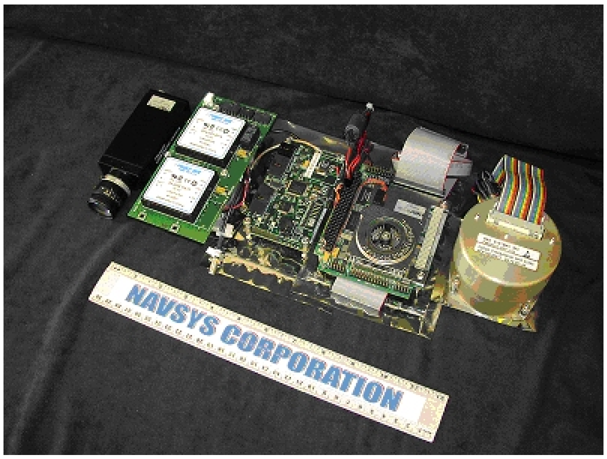

Figure 5 GI-Eye UAV Payload Components

GPS Receiver and Antenna A NovAtel GPS receiver is being used for the GI-Eye. For high accuracy applications, we can use their L1/L2 observations to perform kinematic processing. The default mode is to use either Wide Area Augmentation System (WAAS) corrections or Differential GPS (DGPS) corrections from the Ground Station to provide the sensor coordinates.

IMU and NAVSYS Interface Module (NIM) InterNav supports a number of different IMUs. For the UAV GI-Eye configuration, we selected the BAE Multisensor Inertial Measurement Unit.[7] The NIM is a customized board developed by NAVSYS that provides an adaptable interface between the IMU and single board computer through an RS232 or USB port. It also time synchronizes the IMU and GPS data.

Digital Camera The digital camera uses a high resolution, color CMOS video sensor with a maximum resolution of 1280 x 1024 at 15 frames per second. The standard USB 2.0 interface is capable of transferring data at 480 Mbps and is integrated with a built-in frame buffer to prevent data loss. The camera is plug-n-play and supports Windows 2000/XP. The camera uses a C mount lens with a ½" optical format. A variety of lens options are readily available from a number of manufactures ranging from fixed-focus 6 mm and smaller to 75 mm and zoom lens. Flexibility in lens selection is a key aspect of the payload design because the lens characteristics define a number performance attributes of the system. In operational scenarios where the long distance target identification is important, a lens with a narrow field of view is required. If a significant overlap between images is important for image tracking or mosaic generation, a lens with a wider field of view may be required. Therefore, by simply swapping lenses on the digital camera, different mission objects can be accomplished with minimal effort.

Single Board Computer (SBC) The SBC is the core processing and control element of the payload. It is a Pentium-M CPU-based computer in a PC/104-Plus form factor, which provides a relatively high performance processing platform that is light weight with little power consumption. The integrated USB 2.0, RS232, and Ethernet ports provide a flexible means of interfacing the SBC with the payload components while the video and USB interfaces create a convenient development and debugging environment.

Power Supply The GI-Eye system operates from a 12 VDC power supply. Total power consumption is 35.4 watts nominal and 56 watts peak. A DC/DC power supply is included in the package to power the subsystem components.

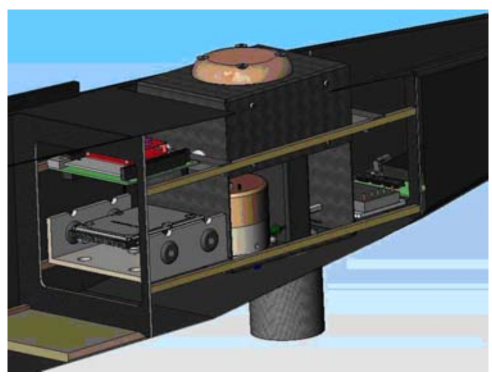

Figure 6 GI-Eye UAV Mechanical Assembly

Figure 7 ARES Unmanned Air Vehicle

Table 1 Payload Weight and Power Summary

Description	Weight (g)	Power (W)
GPS Antenna	145	0.125
GPS Engine	56	1.600
IMU	539	16.850
Digital Camera	176	1.500
Lens	55	0.000
Interface Board	25	0.300
SBC	250	13.000
HDD	115	2.000
Power Supply	105	
Cable Budget	200	
Camera/IMU Platform	300	
	1965	**35.375**
	4.3	**lbs**

GEOREFERENCED INFORMATION MANAGER (GRIM)

The companion product to the GI-Eye is the GeoReferenced Information Manager. GRIM is developed based on an Oracle Application Server architecture. GRIM provides tools to synchronize data between the UAV payload and the GRIM server and to provide management and intelligent search and retrieval of the image data. GRIM leverages the GI-Eye meta-data which provides the precise location and attitude of the sensor images to simplify and streamline feature extraction from the images. The precise sensor meta-data also eliminates the need for expensive and time consuming image processing for generating products such as mosaics or digital elevation models. The interfaces between the GRIM server and the airborne GI-Eye payload are shown in Figure 8.

GRIM adopts an Enterprise Architecture to manage the GI-Eye information. The Oracle database connection is used to synchronize the GI-Eye metadata and image thumbnails between the Oracle Express database in the GI-Eye and the GRIM database. This allows GRIM to use Web Services to prioritize the full image data for transfer across the downlink using FTP ("smart push"). Tools are included in the GRIM server to allow for location-based search and retrieval of the GI-Eye sensor data ("smart pull"). Users can access the GRIM viewing and targeting tools through a web browser as shown in Figure 9 for real-time access to the georegistered imagery. The user can also use GRIM to automatically select multiple images over a target. A web-based user interface is provided to allow the user to select the target pixels in each image. The GRIM server will then automatically calculate the 3D target coordinates and error ellipse from this data and display it to the user (Figure 10).

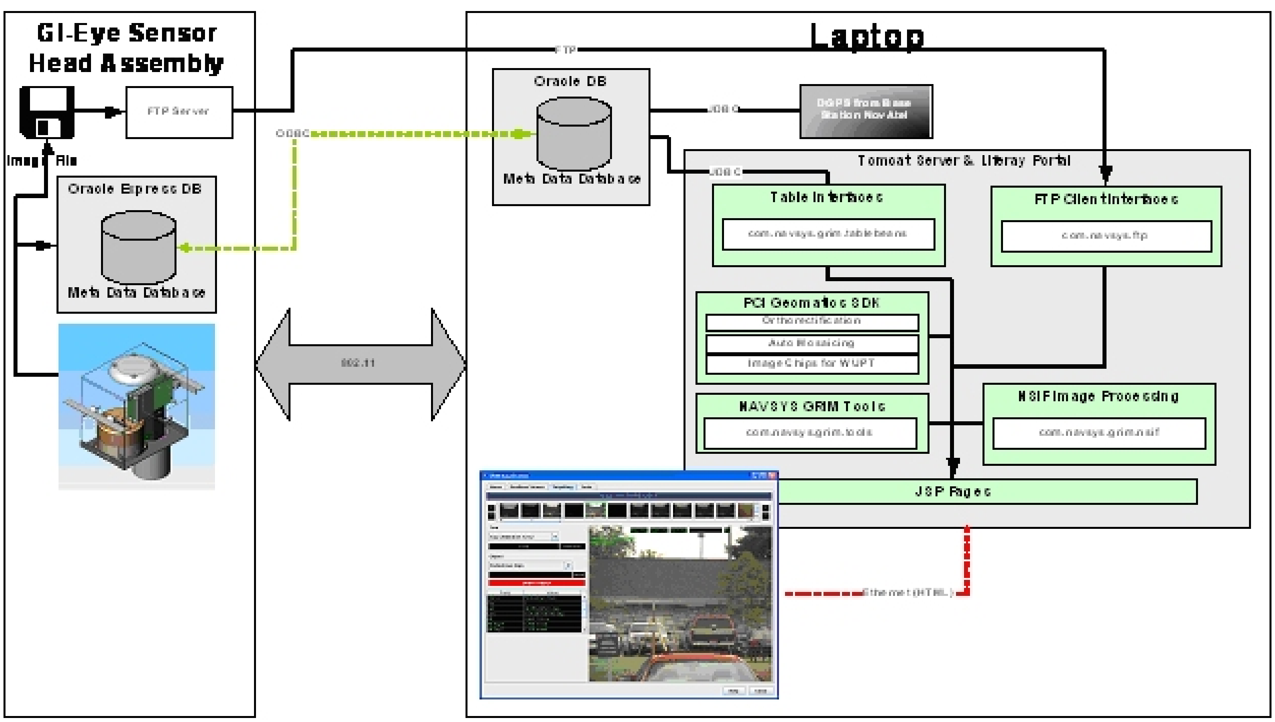

Figure 8 GI-Eye and GRIM Architecture

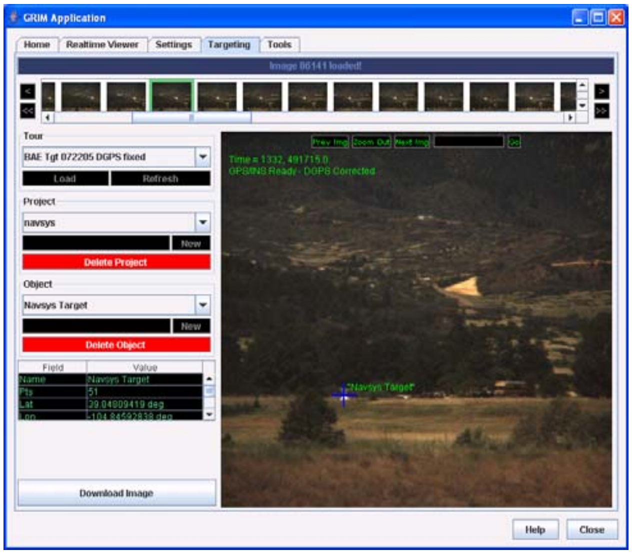

Figure 9 GRIM Web Browser and Image Manager

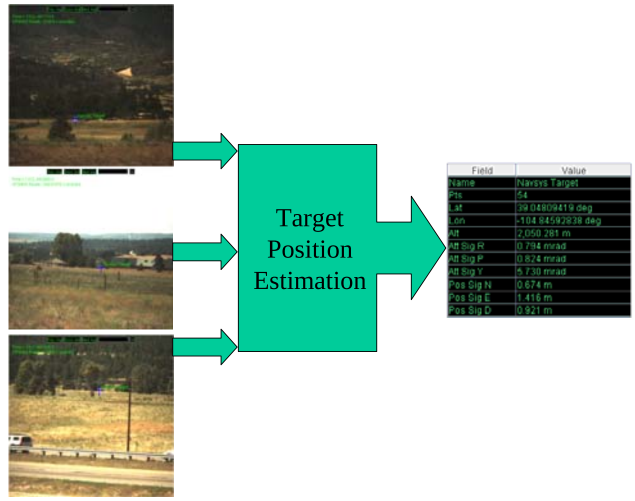

Figure 10 GRIM Precision Targeting Calculation

AUTO-MOSAIC GENERATION

The GRIM product has been designed to optionally include an auto-mosaicing function that can take the down-linked GI-Eye images and create a mosaic in near real-time. This allows the downlinked imagery to be displayed as a registered "overhead" image using existing tools such as FalconView or Google Earth.

The process of mosaicing is joining together two or more overlapping images to form a continuous composite image. The normal method of generating a mosaic is illustrated in Figure 11 and requires intensive image processing to collect ground control points and compute a math model for use in orthorectifying the images and creating the mosaic. With the GI-Eye meta-data, the math model for each image can be explicitly calculated eliminating these time consuming steps.

Figure 12 shows the Auto-Mosaicing process that has been developed to be run on the GRIM Server using PCI Geomatics' Production Workflow products[8]. This uses a recursive process to orthorectify images from the GRIM database and uses these to update the mosaic image. This process can be run in near real-time allowing an overhead view to be generated potentially within minutes of the images being collected. Examples of a mosaic generated from GI-Eye using this product are shown in Figure 13.

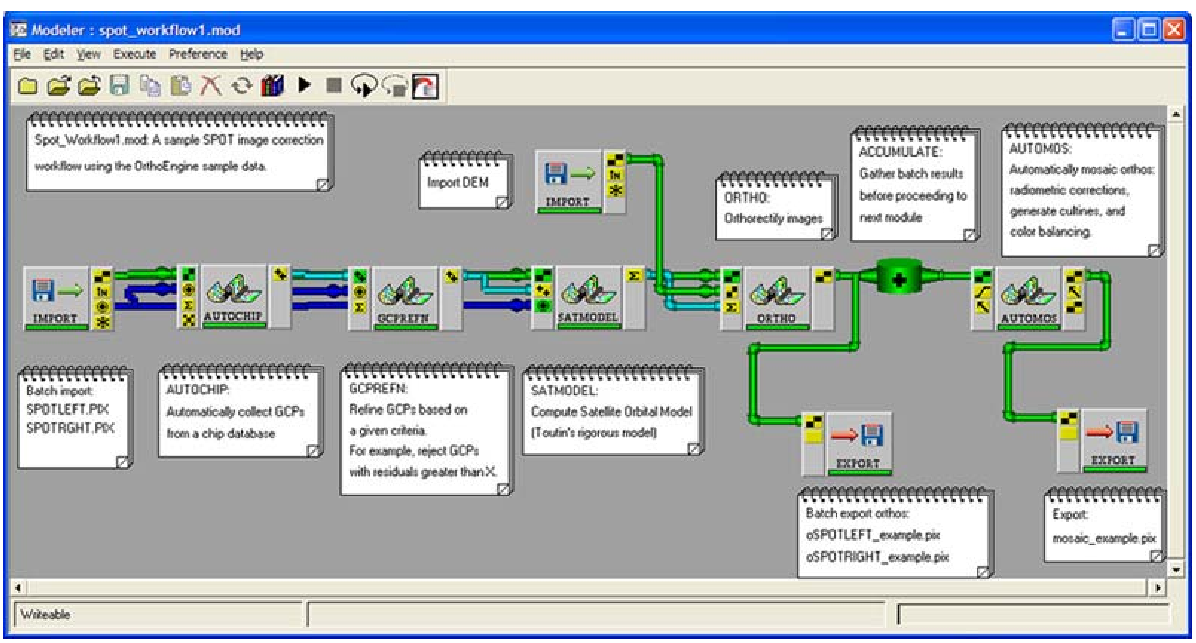

Figure 11 Mosaic generation using PCI Geomatics Tools[8]

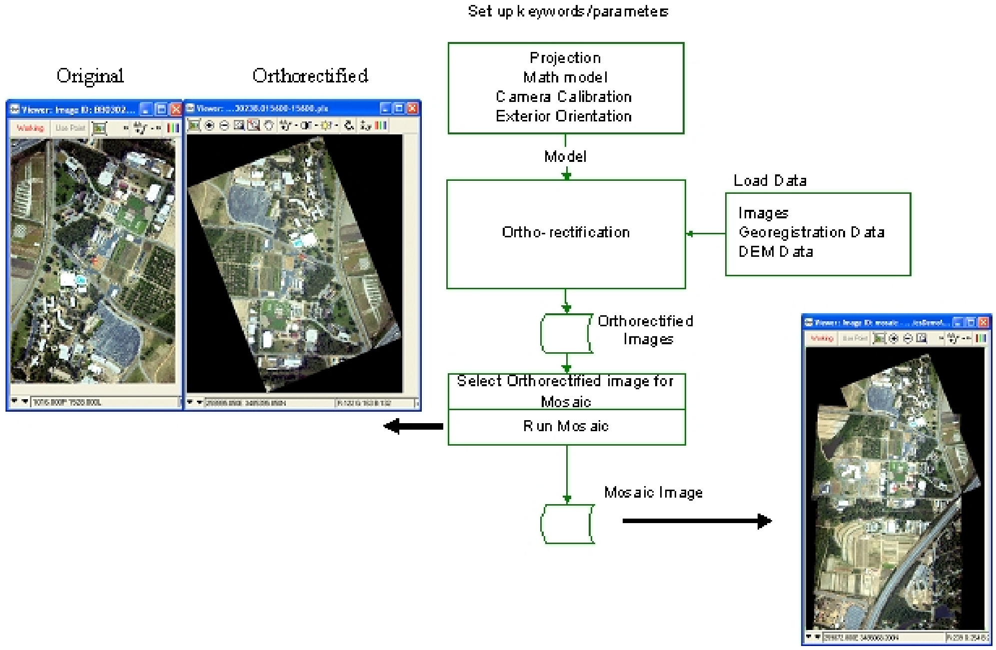

Figure 12 Auto-Mosaic Generation using PCI Geomatics Tools with GI-Eye meta-data

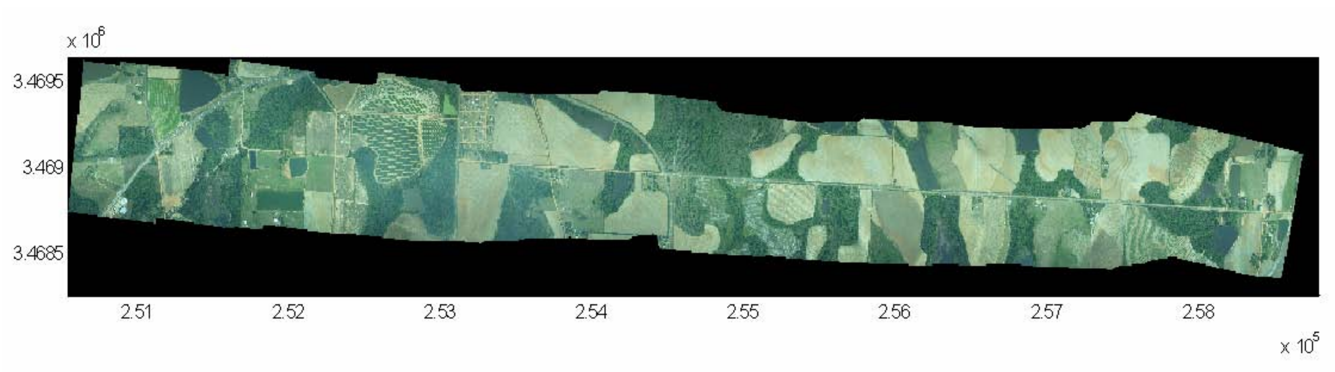

Figure 13 Auto-Mosaic Generated from GI-Eye Flight Test

GRIM FEATURES AND BENEFITS

The GRIM system has been developed based on an Oracle Application Server which incorporates spatial processing in accordance with the open geospatial standards developed by the Open Geospatial Consortium (OGC). This allows the GRIM imagery products to be integrated with Web geospatial tools that are also OGC compliant. An example of an application that is interoperable with the GRIM server is eSpatial's iSMART product[9]. As shown in Figure 14, this allows the GRIM developed mosaics to be viewed in real-time with other data overlays in user customized web pages using only a web browser. The iSMART product also allows geospatial data to be published back into the GRIM server from user entered data on the web page. This allows real-time updates to be made for feature data and real time display of registered airborne imagery collected from the GI-Eye system.

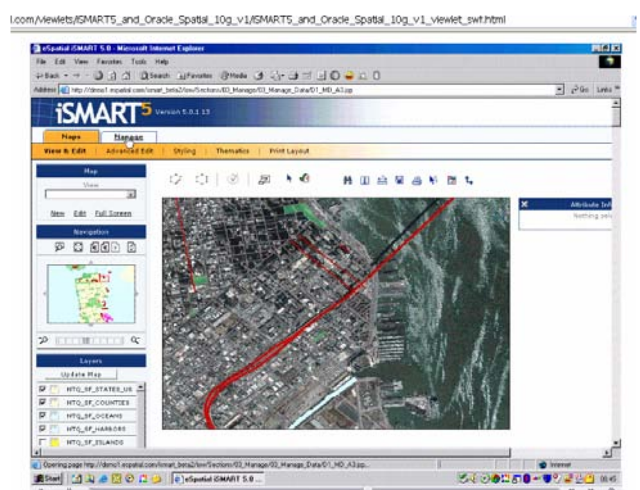

Figure 14 eSpatial's iSMART product

A summary of the features and benefits provided by the GRIM tools set is included below.

Table 2 Summary of GRIM Features and Benefits

Feature	Conventional UAV Approach	GRIM Approach
Imagery Downlink	Streaming video imagery downlinked. Compression needed due to bandwidth constraints compromises on image quality.	High resolution still-images downlinked. Real-time low resolution display provided for User Interface.
Search and Retrieval	Fast-rewind capability provided for review of past data – searches through time only.	Intelligent search and retrieval of imagery data based on time window and/or target coordinates.
Visual Display	Streaming imagery – requires trained operator to interpret "bird's eye" view	Real-time Mosaic generation – minimizes operator training by allowing overlay on existing tools such as FalconView or Google Earth
Targeting	Accuracy of targeting is generally poor due to low resolution metadata and reduced quality imagery	High accuracy targeting based on real-time georeferenced Mosaic (point and click user interface)

SUGGESTED CONCEPT OF OPERATIONS FOR NEAR REAL-TIME MOSAIC GENERATION

Using the GI-Eye and GRIM technology, it would be possible to generate in near real-time a continually updated registered mosaic with an overhead view of the area covered. A potential concept of operations for this capability is illustrated in Figure 15. A network of low-cost persistent UAVs with GI-Eye payloads could be used to collect real-time registered imagery which is then downlinked to a central GRIM server. The imagery can be processed in near real-time creating a registered overhead view in a format that can be used by location servers to provide a current view of the area covered by the UAVs.

CONCLUSION

Near real-time dissemination of georeferenced imagery by a location server can benefit a number of military and civilian applications. The military would benefit from having access to imagery for situational awareness in a format that ground troops can easily use and can readily access using existing Web-based viewing tools. (For Harry Potter fans, this would provide the equivalent capability to the magical *"Marauders Map"*). For civil applications, the same type of situational awareness would benefit disaster recover efforts. For example, lives could have been saved in the Katrina disaster with the ability to provide responders precise geo-registered positions of victims with accurate images depicting their condition and environment. Forest fire hot zones could be accurately identified and located quickly for special treatment. Homeland security, police standoffs or hostage situations could be managed more efficiently with a better outcome because of real time precision image availability that precisely locates all parties.

For commercial location servers, near real-time imagery would address the desire of their customers for more current and accurate data. This would open up new market and service opportunities providing current information on road conditions, weather or even current events (Figure 16). Reducing the age of location server imagery from years to minutes would be a huge leap ahead for this exciting new technology. The GI-Eye and GRIM products are being provided by NAVSYS to enable this next generation advancement.

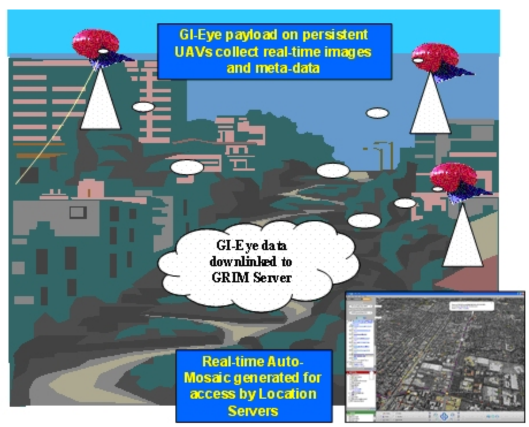

Figure 15 Urban Real-Time Auto-Mosaic Collection Concept of Operations

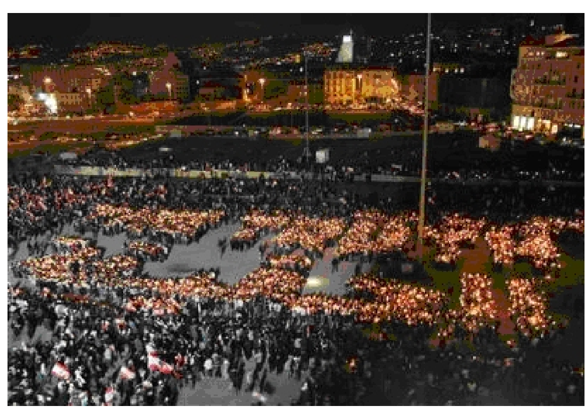

Figure 16 800,000 plus people in Lebanon spelling out the word "Truth" in English and Arabic

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